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<u>TITLE</u>

FIBER TO THE HOME BROADBAND HOME UNIT

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FIBER TO THE HOME BROADBAND HOME UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/437,789

entitled "Full Service Access Network Fiber To The Home System Architecture," which

5   was filed on January 3, 2003. The entire disclosure of United States Provisional

Application No. 60/437,789 is hereby incorporated into the present application by

reference.

BACKGROUND

Field

10   The systems and methods described in this patent document relate generally to

optical networks and more specifically to fiber to the home optical systems.

Description of the Related Art

Optical networks can be used to deliver communication services to businesses

and homes. Optical networks have the capability of delivering a variety of services such

15   as video, data, and telephony services. The optical network devices that are presently

considered for providing residential services typically are devices such as optical

network units that are designed to provide services to multiple residential units and are

not appropriate for use with a single residential unit.

SUMMARY

20   An apparatus and system are provided for delivering communication services

such as video, data and telephony services to individual residential units.

According to one embodiment, an optical network terminal (ONT) for providing

communication services to a single residential unit comprises a passive optical network

interface (PI) circuit, a residential service interface (RSI) circuit, and a power unit. The

PI circuit receives optical signals from an optical fiber and transmits optical signals onto the optical fiber. The PI circuit is adapted to convert received optical signals containing voice information to electrical voice ATM cells, received optical signals containing data information to electrical data ATM cells, and received optical signals containing video

5   signals to electrical video signals. The PI circuit is also adapted to convert electrical voice ATM cells and electrical data ATM cells to optical signals for transmission over the optical fiber.

The RSI circuit that is adapted to convert the electrical voice ATM cells to a telephony format suitable for use at the residential unit and the electrical data ATM cells

10   to a data network format suitable for use at the residential unit. The RSI circuit is also adapted to convert telephony format information received from the residential unit to voice ATM cells and data network format information received from the residential unit to data ATM cells.

The power unit provides power for use in the PI circuit and the RSI circuit. The

15   power unit includes an AC/DC converter for converting ac power received from the residential unit to dc power for use in the ONT and backup batteries for providing power when there is an interruption of the ac power.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an exemplary embodiment of a full service access

20   network;

FIGs. 2A & 2B are block diagrams of exemplary embodiments of full service access networks having different service provision capabilities;

FIG. 3 is a block diagram illustrating input and output connections of an exemplary embodiment of a broadband home unit;

FIG. 4 is a block diagram illustrating exemplary sections of a broadband home unit;

FIG. 5 is a block diagram of an exemplary embodiment of an ATM passive optical network interface block in a broadband home unit;

FIG. 6 is a block diagram of an exemplary embodiment of a residential service interface in a broadband home unit;

FIG. 7 is a block diagram illustrating an exemplary downstream data path in a broadband home unit;

FIG. 8 is a block diagram illustrating an exemplary upstream data path in a broadband home unit;

FIG. 9 is a block diagram illustrating an exemplary timing path in a broadband home unit; and

FIG. 10 is a block diagram illustrating an exemplary fault isolation path in a broadband home unit.

For simplicity and clarity of illustration, elements shown in the figures are not drawn to scale. Also, reference numerals that appear in multiple figures indicate that the exemplary systems illustrated in the figures may have corresponding or analogous elements.

DEFINITIONS AND ACRONYMS

Acronyms

AAL	ATM Adaptation Layer
ABR	Available Bit Rate
AC	Alternate Current
AIS	Alarm Indication Signal

	APD	Avalanche Photo-Diode
	API	Application Programming Interface
	APON	ATM Passive Optical Network
	ARM	Advanced RISC Machine
5	ATM	Asynchronous Transfer Mode
	BIP	Bit Interleaved Parity
	B-ISDN	Broadband Integrated Services Digital Network
	BER	Bit Error Rate
	BHU	Broadband Home Unit
10	BHU200	Broadband Home Unit 200 (First Release Outdoor Unit)
	BLES	Broadband Loop Emulation Service
	BPDU	Bridge Protocol Data Unit
	BPON	Broadband Passive Optical Network
	B-RAS	Broadband Remote Access Server
15	CBR	Constant Bit Rate
	CO	Central Office
	CRC	Cyclic Redundancy Check
	DACT	Deactivate PON_ID
	DBA	Dynamic Bandwidth Allocation
20	DC	Direct Current
	DSP	Digital Signal Processing
	EMI	Electro-Magnetic Interference
	EMC	Electro-Magnetic Compatibility
	EMS	Element Management System
25	E/O	Electrical to Optical
	EOC	Embedded Operations Channel
	EPD	Early Packet Discard
	ERR	Block Error Detection
	FCC	Federal Communications Commission
30	FCS	Frame Check Sequence
	FTS	Fiber Termination Shelf
	FRML	Loss of Downstream Frame
	FSAN	Full Service Access Network

FTTB	Fiber To the Business
FTTC	Fiber To The Cabinet
FTTH	Fiber To The Home
FTTN	Fiber To The Node
GFR	Guaranteed Frame Rate
HEC	Header Error Control
HEG	Head-End Gateway
ID	Identification
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
ITU-T	Telecommunication Standardization Sector of ITU
LAN	Local Area Network
LCD	Loss of Cell Delineation
LED	Light Emitted Diode
LOS	Loss Of Signal
Mbps	Megabits per second
MDCR	Minimum Desired Cell Rate
MIB	Management Information Base
MII	Media Independent Interface
MIPS	Million Instructions Per Second
MIS	Link Mismatch
NM	nano meter
NRZ	Non Return to Zero
OAM	Operations, Administration, and Maintenance
OAML	PLOAM Cell Loss
O/E	Optical to Electrical
OLT	Optical Line Terminal
OMCC	ONT Management and Control Channel
OMCI	ONT Management and Control Interface
ONT	Optical Network Terminal
PCM	Pulse Code Modulation
PEE	Physical Equipment Error
PHY	PHYsical Layer Device

	PLD	Programmable Logic Device
	PI	PON Interface
	PLOAM	Physical Layer OAM cell
	PON	Passive Optical Network
5	POTS	Plain Old Telephone Service
	PPD	Partial Packet Discard
	PPPoA	Point to Point Protocol over ATM
	PPPoE	Point to Point Protocol over Ethernet
	PPTP	Point to Point Tunneling Protocol
10	PVC	Permanent Virtual Circuit
	PVP	Permanent Virtual Path
	QoS	Quality of Service
	RDI	Remote Defect Indication
	RSI	Residential Service Interface
15	SAR	Segmentation And Reassembly
	SD	Signal Degraded
	SDRAM	Synchronous Dynamic Random Access Memory
	SDV	Switched Digital Video
	SFU	Single Family Unit (formerly name of BHU)
20	SIP	Session Initiation Protocol
	SNI	Service Node Interface
	SNMP	Simple Network Management Protocol
	SRS	System Requirements Specification
	SUF	Start-Up Failure
25	SVC	Switched Virtual Circuit
	TBD	To Be Determined
	TC	Transmission Convergence
	TF	Transmitter Failure
	TRS	Technical Requirements Specifications
30	UBR	Unspecified Bit Rate
	UL	Underwriters Laboratories
	UNI	User Network Interface
	UPS	Uninterrupted Power Supply

	UTOPIA	Universal Test and Operations Interface for ATM
	VBR	Variable Bit Rate
	VC	Virtual Channel
	VCC	Virtual Circuit Connection
5	VCI	Virtual Circuit Identifier
	VoATM	Voice over Asynchronous Transfer Mode
	VoIP	Voice over Internet Protocol
	VP	Virtual Path
	VPC	Virtual Path Connection
10	VPI	Virtual Path Identifier
	WAN	Wide Area Network
	xDSL	x Digital Subscriber Line

Definitions

15   **Network Element** - A Network Element (NE) refers to all the equipment (including

shelves, cards, and modules) that is managed by one management entity. No

equipment can belong to multiple NEs at the same time.

Power Shedding - Power Shedding refers to the capability of shutting down

unnecessary services in a power failure event in order to preserve a certain number of

20   hours (e.g. 8) of battery power for defined minimum services.

Circuit - A circuit refers to a set of elements, wherein some or all of the elements in a

first circuit can also be members of the set of elements making up a second circuit.

DETAILED DESCRIPTION

With reference to the figures, shown in Fig. 1 is an exemplary Full Service

25   Access Network (FSAN) **10**. The exemplary FSAN **10** comprises an Optical Line

Terminal (OLT) **12**, at least one Optical Network Terminal (ONT) **100**, and a Passive

Optical Network (PON) **16** coupled between the OLT **12** and the ONT **100** for

transporting voice, data, and/or video information to and/or from the ONT **100**. The

PON optionally could be an ATM Passive Optical Network (APON), a Broadband

Passive Optical Network (BPON), or some other type of Passive Optical Network.

5   The OLT **12** preferably comprises a Fiber Termination Shelf (FTS). The

preferred OLT **12** has a connection to a Voice public switched telephone network

(PSTN) preferably through an optical path **17** and a Head-End Gateway (HEG) **18**. But,

as an option the HEG could be integrated into the OLT **12**. The preferred OLT **12** also

has a connection to a Data ATM network preferably through another optical path **19**.

10   The OLT **12** transfers voice and data information in a downstream direction to the PON

16 for forwarding to one or more ONTs **100** and transfers voice and data information

received from the PON **16** upstream to a voice PSTN and Data ATM network,

respectively. In addition, the preferred OLT **12** has a connection via a data

communication network 20 to an Element Management System **22** for provisioning,

15   error reporting, troubleshooting, testing and other network management operations.

         The preferred ONT **100** is a Broadband Home Unit (BHU). The preferred BHU

complies with the ITU-T G.983 Full Service Access Network (FSAN) requirements. The

preferred BHU **100** provides broadband and narrow-band services to a single residential

unit. The narrow-band services include telephony services such as POTS and ISDN.

20   The broadband services include high-speed data, video, and home networking. The

BHU **100** transports high-speed data and telephony PCM traffic received, via the PON

16, from the OLT **12** to the residential unit and transports high-speed data and

telephony PCM traffic received from the residential unit to the OLT **12**, via the PON **16**.

The BHU **100** also receives video signals via the PON **16** from a video network and provides the video signals to the residential unit.

The preferred PON **16** comprises one or more optical splitters **24** that are coupled between a splitter wavelength division multiplexer (WDM) Cross-Connect **26**

5   and one or more OLTs **100**. The preferred WDM cross-connect **26** has a fiber optic connection to a video network such as CATV or DBS, a fiber optic connection to the OLT **12** and a fiber optic connection to the PON **16**. The WDM provides connections for transferring video information from the video network to the PON **16**, and provides connections for transferring voice and data signals between the OLT **12** and the PON

10   **16**.

Shown in figures 2A and 2B are exemplary block diagrams of FSANs that use OLTs **12** that have different service capabilities. The exemplary FSAN of figure 2A comprises a FTS 18 platform **12A** that is capable of providing data and voice services for up to 2304 residential units. The exemplary FSAN of figure 2B comprises a Fiber

15   FTS 14 platform **12B** that is capable of providing data and voice services for up to 1792 residential units. Primary differences between the two platforms include difference in their overall mechanical dimensions and differences in the number of card slots each platform can support. Each platform preferably houses ATM fabric and centralized timing source (CTS) circuit boards **32**, service node interface circuit boards **34**, and

20   quad passive optical network (PON) circuit boards **36**. The exemplary FTS 18 platform **12A** of figure 2A preferably can include up to 18 quad PON cards and the exemplary FTS 14 platform **12B** of figure 2B preferably can include up to 100 quad PON cards. Preferably each quad PON card **36** is capable of exchanging traffic with four splitter

WDM cross-connects **26**. Each splitter WDM cross-connect **26** is preferably capable of exchanging traffic with the optical splitters **24** illustrated in figure 1, which correspond to a 1:8 optical splitter **38** and eight 1:4 optical splitters **40** of figures 2A and 2B. Each 1:4 optical splitter **40** is capable of exchanging traffic with four BHUs **100**.

5   The exemplary BHU **100**, as illustrated in figure 3, has a number of interfaces for transferring voice, data, video, and other information between a residential unit and an optical network. The exemplary BHU **100** includes an interface for up to four telephony lines such as POTS via RJ-11 connectors. The exemplary BHU **100** also includes an interface for network traffic such as a10/100 Base-T network via RJ-45. The exemplary

10   BHU **100** further includes an interface for video services such as CATV or DBS via an F-connector. The exemplary BHU **100**, in addition includes, an interface for providing alarm and status indication information to the residential unit, an interface for receiving power from the residential unit, and an interface for other optional services. For transferring voice, data, video, and other information between the BHU **100** and an

15   optical network such as a PON, the exemplary BHU **100** includes an interface for exchanging WDM optical traffic over a single fiber **41**. In the example illustrated in figure 3, downstream voice & data is received at a 1490 NM wavelength, downstream video is received at a 1550 NM wavelength, and upstream voice and data is transmitted at a 1310 NM wavelength on the fiber **41**.

20   Overall the preferred BHU **100** is a Fiber-To-The-Home (FTTH) Optical Network Terminal (ONT) that includes a PON interface, provides telephony services, provides data services, provides video services, provides future service options, provides traffic management services, and includes power circuits and status indicators.

With regard to its PON interface, the preferred BHU **100** transmits upstream data & telephony at 1310 NM, receives downstream data & telephony at 1490 NM, and receives downstream Video at 1550 NM. The data rates handled by the preferred BHU **100** include 155.52 Mbps downstream and 155.52 Mbps upstream but may optionally

5   include 622.08 Mbps downstream and 155.52 Mbps upstream, 622.08 Mbps downstream and 622.08 Mbps upstream, or other bit rate combinations. The preferred BHU **100** supports fixed bandwidth allocation and may optionally support dynamic bandwidth allocation.

Regarding the provision of telephony services, the preferred BHU **100** provides a

10   POTS and/or ISDN interface. The transport format in the preferred BHU **100** comprises VoATM/AAL-2 using PVC and CBR. Optionally, the transport format may comprise VoATM/AAL-1 and/or VoIP over ATM (AAL-5) using SVC and rtVBR or other transport formats.

Regarding the provision of data services, the preferred BHU **100** provides a

15   10/100Base-T interface but may provide other interfaces such as a Gigabit Ethernet interface, an ATM Forum Interface, or a USB interface. The preferred BHU **100** employs fixed bandwidth allocation but optionally may employ dynamic bandwidth allocation.

With regard to providing video services, the preferred BHU **100** provides full-

20   bandwidth CATV (54 MHz – 870 MHz) but may optionally provide limited-bandwidth CATV (54 MHz – 370 MHz), DBS (950 MHz – 2050 MHz), Switched Digital Video (SDV), and/or set-top box return. In regards to providing future services options, the

preferred BHU **100** may make provisions for supporting a Home Wired Network and/or a Home Wireless Network.

As illustrated in figure 4, the preferred BHU **100** comprises a main unit **102** and power unit **104**. The exemplary main unit **102** contains a fiber mechanical protector tray

5   **106**, a PON Interface (PI) module **200**, a residential service interface (RSI) module **300**, a future expansion (FE) module **112**, primary electrical protectors **114**, electrical terminals **116**, and status indicators **118**.

The fiber mechanical protector (or fiber tray) **106** provides mechanical protection for the WDM optical fiber **41** received by the BHU **100** to reduce the likelihood of the

10   optical fiber **41** from a PON to the BHU **100** from being damaged by mechanical contacts. The fiber tray **106** provides fiber slack management to prevent stresses/damages during installation and maintenance. The fiber tray **106** also provides fiber jacket termination. Preferably the fiber tray **106** prevents the connection point for the fiber **41** from being accessible to the general public but provides access for service

15   provider technicians.

The PI module **200** provides a physical interface for the fiber **41**. The PI module **200** receives optical signals from the fiber **41**, converts the received optical voice and data ATM signals to electrical ATM cells, and converts the received optical video signals to electrical video signals. The converted electrical ATM cells are then forwarded to the

20   RSI module **300** for further processing and the electrical video signals are forwarded to the primary electrical protectors **114** for forwarding to the residential unit. The PI module **200** also converts electrical voice and data ATM cells received from RSI module **300** to optical signals for transmission over the optical fiber **41**. The PI module **200**

terminates and generates PON Physical Layer including PLOAM cells. The PI module 200 transports ATM cells to and from the RSI module 300 preferably via a Utopia-2 port. The exemplary PI module 200 also receives DC power from the RSI module 300 and derives other necessary voltages on-board.

5   The RSI module 300 processes ATM packets received from the PI module 200, converts the packets to PCM voice and data, and transports the PCM voice and data to the primary electrical protectors 114. The RSI module 300 also receives PCM voice and data from the primary electrical protectors 114 that were received from the residential unit via the POTS and 10/100Base-T Ethernet interfaces at the electrical

10   terminals 116, converts the PCM voice and data to ATM packets, and forwards the ATM packets to the PI module 200 for conversion to optical signals and transmission via the PON. The RSI module 300 receives and transmits ATM cells from and to the PI module 200 preferably via a Utopia-2 interface. The exemplary RSI module 300 processes ATM Layer, ATM Adaptation Layer, and OMCI layer. The exemplary RSI module 300 also

15   provides priority queuing, traffic scheduling, and traffic shaping.

The RSI module preferably includes a central processor that provides central processing services for many circuits and modules in the BHU 100. The exemplary RSI module 300 also provides a processor interface for use in the PI module 200 for control functions and a D.C. power interface for providing power to the PI module 200. The RSI

20   module also preferably provides an additional connector with a Utopia-2 port, processor interface, optional MII interface, and power for future use by an optional future expansion module 112.

The primary electrical protectors **114** provide electrical protection for the PI module **200**, RSI module **300**, FE module **112**, and external interfaces. The primary electrical protectors **114** provide protection against potential hazards such as lightning, power irregularity, and EMI that cables and signal lines connected between the

5 residential unit and the BHU **100** may be subject to by providing protection circuits. The primary electrical protectors **114** preferably provide protection for various interfaces such as POTS and/or ISDN, 10/100Base-T Ethernet, CATV and/or DBS, DC power input, alarm interfaces, and future expansion interfaces. The primary electrical protectors **114** preferably provide protection in accordance with Articles 800-30 and

10 800-31 of the National Electrical Code, ANSI/NFPA 70. Preferably, the primary electrical protectors **114** are physically located separate from other circuits in the BHU **100** such the PI module **200**, the RSI module **300**, and the future expansion module **112**. Preferably the primary electrical protectors **114** are not accessible to the general public but accessible for service provider technicians.

15 The electrical terminals **116** are portion of the main unit that provide physical service connections for the residential unit and test terminals for use by service provider technicians. The electrical terminals **116** are the section of the main unit where the electrical cables that carry electrical signals to the residential unit and the electrical cables that carry electrical signals from the residential unit physically connect to the

20 BHU **100**. The electrical terminals **116** preferably include electrical terminals for POTS and/or ISDN, 10/100Base-T Ethernet, CATV and/or DBS, DC input, alarm interfaces, and future expansion interfaces. The electrical terminals **116** may optionally include test interfaces such as RJ-11 connectors to allow service provider technicians to test

POTS lines, a RJ-45 connector to allow service provider technicians to test a 10/100Base-T port, and an F-connector to allow service provider technicians to test CATV channels and/or DBS channels. Preferably, the electrical terminals **116** are physically located separate from other circuits in the BHU **100** such the PI module **200**,

5   the RSI module **300**, and the future expansion module **112**. Preferably the electrical terminals **116** are not accessible to the general public but are accessible for service provider technicians. The electrical terminals **116** preferably include a control access medium such as a limited access door to prevent public access and to protect electrical terminals and cable connections.

10   Preferably the BHU **100** also includes a future expansion module **112**. The future expansion module **112** optionally provides circuitry, space, physical interfaces and/or features that may be added to the BHU **100** in the future. The future expansion module **112** preferably is capable of transporting ATM cells to and from the RSI module **300** via a Utopia-2 port. The future expansion module **112** preferably provides status

15   information to the RSI module **300**. The future expansion module **112** preferably is configured and controlled by the RSI module **300**, receives power from the RSI module, and provides future interface or feature capabilities such as a home wired networking interface, a home wireless networking interface, extra data ports such as ATM25, and additional processing resources. The future expansion module **112** preferably includes

20   on-board DC/DC converters and/or voltage regulators and provides test ports. The Future Expansion module preferably is contained within an electronic enclosure along with the PI module **200** and the RSI module **300**. Preferably the future expansion

module **112** is not accessible to the general public or service provider technicians and should not be installed in the field.

The exemplary BHU **100** also includes status indicators **118**. The status indicators **118** provide indicators of the status of various subsystems, functions, and/or services of the BHU **100**. The status indicators **118** preferably comprise LEDs that are visible externally to and/or internally in the BHU **100**.

The power unit **104** of the exemplary BHU **100** preferably includes an A/C-to-DC converter **120**, backup batteries **122**, and power indicators **124**. The preferred A/C-to-DC converter has an input for receiving A/C input power from an A/C input power source, an input for receiving 12 VDC from the backup batteries **122**, and an output for delivering a 12 VDC output to components of the main unit **102** of the BHU **100**. The preferred A/C-to-DC converter **120** converts the A/C input power to a 12 VDC output and also bridges the 12 VDC input received from the backup batteries **122** to the12 VDC output when the A/C input is unavailable. The backup batteries **122** preferably comprise multiple batteries connected in series to provide a 12 VDC power source to the A/C-to-DC Converter **120** as a backup power source. The backup batteries **124** preferably comprise C or D type disposable batteries and optionally could be a UPS arrangement.

The preferred power indicator module **124** provides indicators that provide indications of the status of the A/C input and backup batteries **122**. The preferred power indicator module **124** detects when the A/C input is unavailable and when the backup batteries **122** are providing a low voltage output. The preferred power indicator module **124** includes a "Battery Low/Failed" LED, an AC Failed LED, a "Battery

Low/Failed" Audible Alarm, a "Battery Low/Failed" Audible Alarm Manual Disable, and a

serial interface to and from the Main Unit **102**. Preferably the LEDs provide a green

indication when they are indicating that the status of the monitored function is within

tolerances and provide a red or other color indication when they indicate that the status

5   of the monitored function is not within tolerances. Preferably all indicators can be

viewed or heard without opening the housing unit for the power unit **104**.

The BHU **100** employs a power shedding algorithm on A/C Fail with preferably

four programmable configurations. When the BHU **100** is operating on batteries it goes

into a power shed mode. If the AC is restored, the BHU **100** will stop operating in the

10   power shed mode and operate in a full operation mode. Preferably, the customer at

installation is provided with an option of which services will be operational during power

shed mode operation. Preferably the customer can choose one of the following options:

(1) a selected POTS/ISDN port is on; (2) a selected POTS/ISDN port and a selected

data link are on; (3) two selected POTS/ISDN ports are on; or (4) two selected

15   POTS/ISDN ports and a selected data link are on. The power shedding mode allows

the BHU **100** to shut down unnecessary services in a power failure event in order to

preserve a certain number of hours (e.g. 8) of battery power for defined minimum

services.

Now with reference to figure 5, illustrated is a block diagram of an exemplary

20   PON interface module **200**. The PI module is preferably contained within an electronic

enclosure along with the RSI module and the Future Expansion module. The exemplary

PON interface module **200** comprises a dual-port bi-directional WDM **202** that provides

a physical interface for an optical fiber **201** from the Passive Optical Networks (PON).

The dual-port bi-directional WDM **202** also performs a wavelength division multiplexing function in the PI module **200**.

The exemplary PI module **200** also comprises a video optical-to-electrical conversion circuit **204** and a user data optical-to-electrical conversion circuit **206**. The

5 optical-to-electrical conversion circuits **204** and **206**, respectively, convert received optical signals to electrical signals having video content and electrical signals having user data content.

The exemplary PI module **200** further comprises a clock and data recovery circuit **208**. The clock and data recovery circuit **208** recovers clock information and data and

10 telephony ATM cells from the electrical signals having user data content. The clock and data recovery circuit **208** also processes PON physical layer according to the ITU-T G.983.1.

The exemplary PI module **200** also comprises a video signal recovery circuit **210**. The video signal recovery circuit **210** is operative to recover CATV and/or DBS video

15 signals and to provide the recovered CATV and DBS video signals to the primary electrical protectors **114**.

The exemplary PI module **200** also comprises a PON transceiver **212**. The PON transceiver **212** transports ATM cells to and from the RSI module **300** preferably via a Utopia-2 port **214**. The PON transceiver **212** also preferably provides status information

20 to the RSI module **300**.

The exemplary PI module **200** comprises a user data electrical-to-optical conversion circuit **216**. The electrical-to-optical conversion circuit **216** converts electrical ATM cells received from the PON transceiver **212** to optical signals and

forwards the optical signals to the dual-port bi-directional WDM **202** for transmission over the optical fiber **201**.

The exemplary PI module **200** comprises a control PLD circuit **218**. The control circuit **218** receives control instructions from the RSI module **300** and, based on those control instructions, exchanges control, status, and test instructions and information with other components of the PI module **200**. The control circuit **218** also preferably provides status information to the RSI module **300** and provides test ports and loop-backs.

The exemplary PI module **200** further comprises a power distribution circuit **220**. The power distribution circuit **220** preferably receives power from the RSI module **300**. The power distribution circuit **220** also preferably comprises on-board DC/DC converters and/or voltage regulators and possible fusing for meeting the power needs of the PI module **200**.

Now with reference to figure 6, illustrated is a block diagram of an exemplary Residential Service Interface (RSI) module **300**. The RSI module **300** transports ATM cells to and from the PI module **200** via a Utopia-2 port **301**. The RSI module **300** also preferably transports ATM cells to and from the future expansion module **112** via another Utopia-2 port **303**. The RSI module **300** preferably configures and controls the whole BHU **100** in accordance with requests by the OLT **12** via OMCI cells. The RSI module **300** preferably collects status information from various components of the BHU **100** and transports the status information to the OLT **12** via OMCI cells.

The exemplary RSI module **300** comprises a communication processor **302**. The communication processor **302** processes and manages ATM Layer, ATM Adaptation

Layer, and OMCI layer. The communication processor **302** also provides priority

queuing, traffic scheduling, and traffic shaping. The communication processor **303**

performs networking processing, protocol processing and central control and status

collection. The communication processor **303** is also usable for testing and operation of

5   other modules and components in the BHU **100**.

The exemplary RSI module **300** also comprises supporting elements for

supporting the operation of the communication processor **302** such as a crystal

oscillator **307**, memory **309** such as SDRAM, and transceiver and buffer circuits **311**,

which allows for an expansion bus for a future expansion module.

10   For providing telephony services, the exemplary RSI module **300** comprises a

DSP **304** for processing voice channels. The DSP **304** may also be used for voice

enhancements such as compression. The exemplary RSI module **300** also comprises a

quad CODEC **306** and a quad SLIC **308** for further processing telephony signals. The

exemplary RSI module **300** also comprises a MLT circuit **310** for providing remote

15   mechanized line-testing capability for multiple POTS/ISDN interfaces. The POTS/ISDN

interfaces are coupled to the primary electrical protectors.

The exemplary RSI module **300** preferably comprises a PCM timing circuit **313**.

The PCM timing circuit **313** preferably includes a phased locked loop circuit for allowing

for voice processing to be phase locked to the system timing reference.

20   For providing data services, the exemplary RSI module **300** comprises a 10/100

Base-T Ethernet Physical circuit **312** and a magnetic circuit **314** for providing a 10/100

Base-T Ethernet interface. The 10/100 Base-T Ethernet interface is coupled to the

primary electrical protectors.

The exemplary RSI module **300** preferably comprises a magnetic and fusing

circuit **316** for receiving power from the electrical terminals and for passing the received

energy to a DC circuit **318**. The DC circuit **318** preferably comprises DC/DC converter

and/or voltage regulator circuits. The DC circuit **318** provides energy for meeting the

5   power needs of the RSI module **300** and for providing energy to meet the power needs

of the PI module **200** and the Future Expansion module **112**. The exemplary RSI

module **300** also preferably comprises voltages and battery monitors **320** for monitoring

voltages and battery levels in the BHU **100**.

The exemplary RSI module **300** preferably provides a system monitoring

10   capability. To support the system monitoring capability, the RSI module **300** preferably

comprises a push button reset circuit **322** that provides a mechanism for resetting the

unit. The RSI module **300** also preferably comprises a control PLD **324**, LEDs **326**, and

an inventory circuit **328**. The LEDs **326** preferably provide visual status indications for

link status, voice status, CATV status, DBS status, data link, and data activity. Status

15   indications may also be transmitted in a manner that allows a technician to receive them

electronically. Test capabilities of the exemplary RSI module **300** includes test

points/ports, USB debug port, push-button reset (forced) and watchdog timers.

The exemplary RSI module **300** also includes boot flash memory for use by

various modules such as the PI Module **200**, the RSI module **300**, and the FE module

20   **112** when booting up. The exemplary RSI module **300** may optionally include

development Interfaces such as a JTAG port and/or USB port for use during

development, manufacturing, and/or testing.

Regarding the operation of the exemplary RSI module **300**, the exemplary RSI module **300** transports ATM cells to and from the PI module via a Utopia-2 port. The exemplary RSI module **300** is capable of transporting ATM cells to and from the Future Expansion module via another Utopia-2 port. The exemplary RSI module **300** can

5   configure and control the entire BHU **100** upon request by the OLT via OMCI cells. The exemplary RSI module **300** collects status information from various BHU modules, maps status information into OMCI cells, and transports OMCI cells back to the OLT. The exemplary RSI module **300** provides power to the PI module and the Future Expansion module. The exemplary RSI module **300** processes and manages ATM

10   Layer, ATM Adaptation Layer, and OMCI layer. The exemplary RSI module **300** provides 4 POTS and 1 10/100Base-T Ethernet interfaces. The exemplary RSI module **300** includes an on-board communication processor for networking processing, protocol processing and central control and status collection. The exemplary RSI module **300** provides priority queuing, traffic scheduling, and traffic shaping for ATM traffic. The

15   exemplary RSI module **300** monitors voltages and battery levels. The exemplary RSI module **300** accommodates inventory data storage. The exemplary RSI module **300** may optionally provide traffic policing for ATM traffic if an ATM UNI interface is added.

Referring now to figure 7 illustrated is the signal flow in the preferred BHU **100**. In the downstream direction, optical signals are received from a PON via an optical fiber

20   **41**and directed to the dual port bi-directional WDM circuit **202** in the PI module **200**. In the WDM circuit **202**, the optical signals are wavelength de-multiplexed into two separate ports. Preferably 1490 NM signals are received that contain voice, data, and control information and 1550 NM signals are received that include video information.

The 1490 NM signals are preferably routed to one port and the 1550 NM signals are routed to another port.

The 1550 NM optical signals containing video information are directed to an optical-to-electrical converter **204** where the signals are converted to electrical signals.

5 The converted electrical signals are directed to a video recovery circuit **210** where the video signals are recovered. The recovered video signals are amplified then directed in turn to the primary electrical protectors **114**, electrical terminals **116**, and ultimately to a residential unit.

The 1490 NM optical signals containing voice, data, and/or control signals are

10 directed to an optical-to-electrical converter **206** where the signals are converted to electrical signals. The converted electrical signals are directed to a clock and data recovery circuit **208** where clock and NRZ traffic data are recovered.

A system clock reference is derived from the recovered incoming clock. The BHU **100** also uses the recovered incoming clock to transport traffic data upstream. The BHU

15 **100** provides the system clock reference to internal devices that process PON layer and PCM voice traffic.

The PON transceiver **212** receives the recovered traffic data, which may include voice, data, and control information. The PON transceiver **212** converts the traffic data from serial to parallel and performs bit and byte synchronization, searches for cell

20 boundaries and delineates ATM cells. The PON transceiver **212** also checks and corrects HEC with regard to the ATM cells. The ATM cells are processed using VPI cell filtering, header translation, and optional de-churning. A churning key will be provided for upstream traffic if requested by the FTS OLT. Voice, data, signaling, control, and

OMCI cells are passed through a Utopia-2 interface to the communications processor **302** in the RSI module **300**. Idle cells are not passed but discarded. PLOAM cells are framed up, recovered, extracted, and terminated at the PON Interface module **200**. A 1-KHz reference clock is recovered from synchronization field of the first PLOAM cell and

5 is used to synchronize with a local timing counter, so the BHU local timing counter can lock on the FTS OLT counter.

Grants are extracted from PLOAM cells. CRC for each group of grants is checked. Grants are processed when there no CRC errors. The results determine bandwidth allocation, cell slot assignment, ranging, and type of data that can be sent at

10 each time slot.

Messages are also extracted from PLOAM cells. Message CRC is checked. If there is no CRC error, message will then be processed. All OAM related alarms or threshold-crossing alerts triggered by events are transported via messages in PLOAM cells. Also, all ranging related messages are mapped in the message field of PLOAM

15 cells. Once the BHU is in frame sync, the message field is processed independent of the correctness of PLOAM cell header. No error correction is applied to this received message field.

BIP8 of PLOAM cell is also verified. Each BIP8 in each PLOAM cell is used for monitoring the BER on the downstream link. Each BIP8 covers 27 ATM cells and its

20 PLOAM cell. BIP8 is an estimate for the real BER when the BER is smaller than 10E-04.

The PI module monitors all OAM errors related to PON Physical Layer such as TF, LOS, PEE, SUF, OAML, SD, LCD, FRML, ERR, MEM, DACT, and MIS.

The RSI module **300** receives voice, data, signaling, control and OMCI cells from the PI module **200** via a Utopia-2 interface. The RSI module **300** provides priority queuing, scheduling, traffic shaping, Ethernet bridging, and other services. The RSI module **300** also manages physical interfaces such as Utopia-2, 10/100Base-T, and

5   peripheral ports.

The RSI module **300** terminates ATM AAL-1/2 voice cells. The communication processor **302** routes PCM voice traffic to the DSP **304**. The DSP **304** processes voice channels. The PCM voice channels are sent in turn to the CODEC **306**, the SLIC **308**, the primary electrical protectors **114**, the electrical terminals **116**, and finally to the

10 residential unit via telephony lines.

The RSI module **300** also terminates ATM AAL-5 data cells. The communication processor **302** routes user data traffic to the Ethernet PHY device **312**. User data traffic from Ethernet PHY device **312** is sent in turn to the primary electrical protectors **114**, the electrical terminals **116**, and finally to the residential unit via a data port such as

15 10/100Base-T Ethernet.

With reference to figure 8, in the upstream direction, PCM voice traffic is received from a residence via telephony lines. The PCM voice traffic is directed to the electrical terminals **116** and then to the primary electrical protectors **114**. From there, the PCM voice traffic is sent to and processed, in turn, at the SLIC **308**, CODEC **306**, and DSP

20 **306**. The communication processor **302** next segments and assembles the PCM traffic data into ATM AAL-1/2 cells.

User data traffic is received from a residence via a data port. The User data traffic is directed, in turn, to the electrical terminals **116**, the primary electrical protectors

114, and then to a PHY device **312**. The communication processor **302** next segments

and assembles the User data traffic into ATM AAL-5 cells. All ATM traffic from the RSI

module **300** is queued, scheduled, possible shaped if required, and finally transmitted to

the PI module **200** via a Utopia-2 interface.

5　　　　The PON transceiver in the PI module **200** then combines received traffic from

the RSI module **300** with data generated in the PI module **200**, such as PLOAM cells

and mini-slots, and transmits the combined information onto a single parallel bus to the

E/O conversion circuit **216**. The data is preferably formatted according to the G.983.1

upstream format. The E/O conversion circuit **216** serializes and converts the data to an

10　　optical signal. The optical signal is wavelength multiplexed at the WDM device **202**,

transmitted onto a fiber at a 1310 NM wavelength, and transported upstream to the FTS

OLT via a PON.

　　　　Figure 9 illustrates exemplary timing paths in the exemplary BHU **100**. Illustrated

are four timing paths: system timing references embedded in data stream, PCM timing

15　　signals locked to system timing reference, data timing signals locked to a free-run clock,

and embedded video timing signals. The clock signal recovered by the clock and data

recovery circuit **208**, which is recovered from the PON, is used for timing all outputs of

the BHU **100**. In circumstances wherein the BHU is not connected to the PON, such as

during certain maintenance operations, a free run clock can be used for system timing.

20　　　　Figure 10 illustrates exemplary fault isolation mechanisms in the exemplary BHU

100 that provide remote testing capabilities. A F4/F5 loopback of ATM cells is provided

to isolate the residential unit interfaces. The F4/F5 loopback provides a loop between

the OLT **12** and the communication processor **302** to allow for remote fault condition

isolation testing for determining if a fault exists between the OLT **12** and the

communication processor **302**. In the voice path, loopbacks exist at the DSP **304**,

CODEC **306**, and SLIC **308** for remotely determining if any of those devices are

producing faults. In the data path, a loopback exists in the Ethernet PHY interface **312**

5   for remotely determining if the Ethernet PHY **312** is producing a fault. Also, a RAM

loopback test is provided for remotely determining if a fault condition exists with the

RAM **309**.

With regard to telephonic services, the preferred BHU **100** supports up to four

POTS interfaces. The POTS interface preferably comprises a standard RJ-11

10   connector. The preferred BHU **100** operates PON interface and voice traffic with clock

extracted from the PON interface. The preferred BHU **100** supports Constant Bit Rate

(CBR) for telephone services also supports rtVBR (real time variable bit rate). The

preferred BHU **100** is capable of providing telephony services using VoATM AAL-2

transport. The preferred BHU **100** supports GR-303 and INA TDM network logical

15   interfaces. The preferred BHU **100** supports Robbed-Bit CAS for POTS interface. The

preferred BHU **100** complies with BLES 1.0, ATM Forum VMoA-000145, Profile 9:

G.711 PCM with 44-Byte packet size. The preferred BHU **100** provides echo

cancellation according to G.168. The preferred BHU **100** provided fax/modem tone

detection and response appropriately such as no echo cancellation and voice

20   compression. The preferred BHU **100** supports mu-law coding. The combination of the

preferred BHU **100** and an external HEG provides all CLASS features and on-hook

transmission capabilities. These services meet the requirements of Section 3.4 of GR-

909. The preferred BHU **100** is able to set loop-back configuration before SLIC and

after SLIC. The preferred BHU **100** provides Mechanize Loop Test (MLT) capabilities that meet the requirements of GR-909. The preferred BHU **100** provides SIP capability.

The preferred BHU **100** can optionally support an ISDN interface in place of or in combination with a POTS interface or some other interface. The preferred BHU **100**

5 can optionally support real-time Variable Bit Rate (rtVBR) for telephony services. The preferred BHU **100** may optionally provide Mechanize Loop Test (MLT) capabilities. The preferred BHU **100** may optionally be capable of providing voice/telephony services using VoATM AAL-1 transport. The preferred BHU **100** may optionally be capable of providing voice/telephony services using VoIP over ATM AAL-5 transport. The

10 preferred BHU **100** may optionally support voice compression. The preferred BHU **100** may optionally detect fax and analog modem and be capable of processing these non-compressing data formats appropriately. The preferred BHU **100** may optionally support the following TDM network logical interfaces: TR-08 Mode 1 & 2, V5.1, and V5.2. The preferred BHU **100** may optionally support 2B+D CCS for V5.x ISDN

15 interface. The preferred BHU **100** may optionally support 3-DS0 CCS for GR-303 ISDN interface. The preferred BHU **100** may optionally comply with others ATM Forum VMoA-000145 profiles. The preferred BHU **100** may optionally comply with Megaco H.248. The preferred BHU **100** may optionally support other vocoders. The preferred BHU **100** may optionally provide A-law coding.

20 With regard to data services, the preferred BHU **100** supports one Ethernet 10/100Base-T data interface. The Ethernet 10/100Base-T data interface preferably comprises a standard RJ-45 connector. The connection is preferably a standard DCE connection. The preferred BHU **100** is able to set 10/100Base-T Ethernet interface for

10BaseT or 100BaseT with half-duplex or full-duplex or auto-sense configuration. The default configuration preferably is auto-sense. The preferred BHU **100** is able to provide information regarding the operational state of Ethernet interface to the OLT **12**. Preferably the OLT **12** enables or disables the Ethernet interface in the preferred BHU

5   **100**. The preferred BHU **100** supports Unspecified Bit Rate (UBR) and UBR with Minimum Desired Cell Rate (MDCR) for data services with the default preferably being UBR. The BHU optionally supports non-real-time Variable Bit Rate (nrtVBR). The preferred BHU supports both IEEE 802.3 and Ethernet frame formats.

The BHU **100** may optionally provide an ATM UNI interface. If the BHU provides

10   an ATM UNI interface, the BHU **100** preferably supports ATM Forum UNI 3.1 and/or ATM Forum UNI 4.0. If the BHU **100** supports ATM UNI interface, the BHU preferably has the ability to simultaneously support both ATM Forum UNI 3.1 and ATM Forum UNI 4.0 on all of its ATM UNI interfaces.

The BHU **100** preferably supports PPP over Ethernet by forwarding PPPoE

15   packets between LAN and WAN. The preferred BHU **100** will not need to take an active part in the discovery phase, but will permit the passage of PPPoE frames between LAN and WAN ports. The BHU **100** preferably provides a PPPoE only mode, whereby the only frames forwarded are those with EtherTypes of 0x8863 and 0x8864. This provides a method of filtering local LAN traffic from WAN-bound traffic. This ensures that local

20   LAN traffic will not be bridged onto the WAN interface, saving bandwidth on the WAN interface. The preferred BHU **100** supports the spanning tree function described in IEEE 802.1D. This function could be enable/disable remotely via the OLT **12**. The preferred BHU **100** supports broadcast and multicast traffic forwarding. Broadcast or

multicast traffic from the LAN is preferably forwarded to all configured WAN ports. Broadcast or multicast traffic from the WAN ports is preferably forwarded only to the LAN port, not to the other WAN ports.

The BHU **100** preferably provides a minimum of 250 filter entries that are shared between static entries and dynamic entries. The proportion of entries allocated to each type preferably is not fixed and any entries not used for static entries are preferably available for dynamic entries. At least 25% of the filter table size preferably is available for static entries. Furthermore, the entries preferably are shared across all LAN and WAN bridge ports. Although many WAN ports may be configured, preferably a single WAN port and single LAN are configured. Therefore the filter table entries are preferably shared in a flexible manner between bridge ports. The table entries preferably are split between static and dynamic filter tables, with up to Filter Statistics. For dynamic filtering, the filter table preferably is updated from the MAC self-learning process by adding the source MAC addresses of received upstream and downstream packets to the dynamic filtering database (if not already present). If new static entries are configured and the filter database is full, then the oldest dynamic entries preferably are removed to allow the new static entries to be added to the filter database. If the database is full, then the oldest dynamic entry preferably is removed from the database and the new entry added in its place. The preferred BHU **100** maintains a count of the number of times this circumstance occurs. The aging timeout for dynamic entries preferably is 300s by default, but preferably is configurable from the OLT **12** in the range of 10s-10^6s (11.57 days) in multiple steps.

Preferably, it is possible to enable/disable learning under the OLT **12** control on a

BHU basis. The bridge function preferably provides the filtering function process

defined in IEEE 802.1D. It preferably provides static and dynamic filtering capabilities.

The BHU **100** preferably supports the learning bridge function described in IEEE

5   802.1D. This function preferably can be enabled/disabled remotely via the OLT **12**.

Initially the bridge will not know the addresses of the hosts connected to the LAN and

WAN interfaces. When it receives a packet from a host, it will examine the source MAC

address and store it in the filter table along with the port number on which the packet

was received; i.e. it will 'learn' the MAC address. If the packet was from the LAN

10   interface, it will forward it to all configured WAN ports. If the packet was received from a

WAN port, it will be forwarded to the LAN port only. Subsequently it may receive a

packet with a destination address that is present in the filter table; i.e. an address that

has been learnt. The port number stored in the filter table will tell the bridge which port

this host is connected to. The bridge will then forward the packet on this port. If it

15   happens that the port is the same one as the packet was received on, then the packet is

not forwarded, it is just dropped. (This situation will occur for traffic within entirely within

the LAN or WAN).

The BHU **100** may optionally have an ATM Forum or USB interface for data

services. HomePNA optionally may be supported via the Ethernet interface using a

20   HomePNA to Ethernet bridge device. The BHU **100** preferably supports native LAN

service set-up and tear down as per Appendix I.2.13, I.2.14 ITU-T G.983.2. PPPoA

preferably is implemented if the BHU **100** contains an IP router. Such a router acts as

the default gateway for the home network. The BHU preferably provides PPTP to

PPPoA relay function. The BHU **100** preferably supports Available Bit Rate (ABR) and Guaranteed Frame Rate (GFR) with the default of UBR.

With regard to video services, the preferred BHU **100** supports Direct-To-The-Home (DTTH) video transport using WDM multiplexing. The optional video "capable"

5   interface supports CATV (54 MHz – 870 MHz). The BHU may optionally include video "capable" optional feature and is video "ready", that is, capable of providing video services via a remote software download and/or provisioning message. The BHU video-receiver wavelength preferably complies with the ITU-T Draft G.983.3 wavelength-allocation plan. The optional video interface preferably comprises a standard

10   75-Ω F-type female coaxial connector that supports standard RG-6 coaxial cable. With use of the BHU **100**, installation of video service preferably does not impact service to any other customer on the PON and does not impact delivery of other services to the same BHU. The BHU **100** preferably is able to turn on/off the CATV output. The BHU **100** preferably is able to detect the "live" presence of the CATV input. The CATV-based

15   video system supports analog and/or digital video.

The preferred BHU **100** optionally has a DBS video interface (950 MHz – 2050 MHz) and can turn on/off the DBS output. The preferred BHU **100** is able to detect the "live" presence of the DBS input. The CATV-based video system preferably supports 64-QAM digital video. The BHU **100** preferably provides a digital based return path.

20   Switched Digital Video (SDV) optionally may be supported preferably when 622.08-Mbps downstream is implemented. The CATV-based video system preferably supports 256-QAM digital video.

The BHU **100** optionally has have several modes of usage such as a BHU installation mode, a BHU removal mode, a BHU fault management/detection/prevention mode, a BHU provisioning mode, a BHU surf net mode, a BHU watch TV mode, and a BHU phone call mode.

5   The BHU installation mode may include Power ON, POST, Ranging, OMCC establishment, Persistence Retrieval, MIB Synchronization, and others. The BHU removal mode may include BHU reinstallation, BHU move to new location, and others. The BHU Fault Management/Detection/Prevention mode may include Component Failure / Fault Isolation, Manufacturing Component Failure / Fault Isolation, POST

10   Component Failure, MLT, OAM, Check Video Status, Check A/C Power Status, Check Home Ethernet Link Status, Input Power Change such as A/C failure and Switch to D/C, D/C low, and D/C failure, High Power on SLIC, High Current on SLIC, Get Inventory, MIB Audit / Resynch, and others. The provisioning mode may include Ethernet Set up / Tear down, POTS Set up / Tear down, Video enable/disable, Power Shedding Strategy

15   (1-4) Setting, Software Download such as New Version and Old Version, and others. The Surf Net mode may include MAC Aging and Too Many Users (MACs). The Phone Call mode may include originate call (GR-303) BLES (DTMF), originate call (GR-303) BLES (rotary phone), terminate call (GR-303) BLES, send fax (Modem / FSK), receive fax, modem call, and others (such as Silence, Echo, Call Waiting, Caller ID, Security

20   System).

The structural arrangements and steps described herein and shown in the drawings are examples of structures, systems, or methods having elements or steps corresponding to the elements or steps of the invention recited in the claims. This

written description and drawings may enable those skilled in the art to make and use

embodiments having alternative elements or steps that likewise correspond to the

elements or steps of the invention recited in the claims. The intended scope of the

invention thus includes other structures, systems, or methods that do not differ from the

5   literal language of the claims, and further includes other structures, systems, or

methods with insubstantial differences from the literal language of the claims.